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Environmental Sustainability Abstracts

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A breath away from breakthrough: evaluating Bluezone's efficiency in capturing sevoflurane

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236

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INTRODUCTION

Volatile inhaled anesthetics such as sevoflurane are routinely vented through scavenging systems and released directly into the atmosphere contributing to healthcare-associated greenhouse gas emissions.[1,2] Sevoflurane has a reported 100-year global warming potential (GWP_{100}) of approximately 144, meaning it has 144 times the warming impact of carbon dioxide, with an atmospheric lifetime of approximately five years.[3] Technologies that enable capture and reprocessing of waste anesthetic gases may reduce this environmental impact. BlueZone has developed a capture system designed to adsorb anesthetic gases under clinically relevant conditions; however, its adsorption performance across varying flow rates has not been fully characterized.

METHODS

A benchtop experimental system was designed to evaluate the adsorption efficiency and breakthrough behavior, and saturation characteristics of sevoflurane using BlueZone canisters. Sevoflurane (2%) was delivered under standardized anesthetic conditions at multiple flow rates (0.5cc/min, 2 cc/min, 6 cc/min, and 15 cc/min) using a simulated 40-year old, 70 kg adult patient model. Gas concentrations were continuously monitored using a sideline anesthesia gas analyzer. The point of breakthrough (POB) was defined as the time to initial detection of sevoflurane by sideline gas analysis, with breakthrough declared when concentrations exceeded 100 ppm. The point of saturation (POS) was defined as the time required to reach 80% of maximal adsorption capacity. Canister mass gain was measured to estimate adsorption capacity, and environmental parameters including temperature and humidity were recorded throughout testing. Two types of Deltazite were tested with three trials of each type per flowrate.

RESULTS

BlueZone canisters effectively adsorbed sevoflurane across all tested flow rates. Measurable mass gain was observed under all conditions, with average mass gain at breakthrough of 260.62 ± 15.85 g at 0.5 cc/min, 212.48 ± 5.06 g at 2 cc/min, 403.11 ± 2.66 g at 6 cc/min, and 344.76 ± 9.88 g at 15 cc/min. Breakthrough time decreased with increasing flow rate, occurring at 47 h 15 min ± 5 min at 0.5 cc/min, 6 h 32 min ± 4 min at 2 cc/min, 3 h 57 min ± 0.19 h at 6 cc/min, and 1 h 29 min ± 0.18 h at 15 cc/min, demonstrating an inverse, approximately exponential relationship between flow rate and adsorption duration. Variability in maximum binding capacity was observed across conditions, with recorded humidity levels appearing to affect total adsorption capacity, while flow rate influenced both breakthrough time and maximum binding capacity.

DISCUSSION

BlueZone canisters effectively captured sevoflurane across a range of clinically relevant flow rates, with predictable reductions in breakthrough time as flow increased. Adsorption capacity and breakthrough behavior were influenced by both flow rate and environmental conditions, including humidity. Desorption testing demonstrated the feasibility of recovering captured sevoflurane, supporting the potential for anesthetic gas reuse. These findings support further evaluation of this technology under operating room conditions to reduce the environmental impact of inhaled anesthetics.

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Extending the life of anesthesia breathing circuits: safety, sustainability, and the urgent need for consensus guidelines in Canada

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130

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INTRODUCTION

Operating rooms generate up to 70% of hospital waste, highlighting the need for greener practices. Routine reliance on disposable equipment produces unnecessary waste and increased costs.

Anesthesia breathing circuits (ABCs) connect patients to anesthesia machines to deliver oxygen and anesthetic gases, while eliminating carbon dioxide. ABCs may be single-use, extended-use with new bacterial/viral filters for each patient, or reusable after sterilization. Concerns about cross-contamination have led to routine single-use disposal of ABCs, regardless of procedure length, contributing substantially to waste.

Despite growing interest in sustainable anesthesia, adoption of extended-use ABCs in Canada remains limited and inconsistent. In contrast, many European jurisdictions permit extended use with appropriate filters[1]. The lack of consensus among anesthesia professional societies across continents has resulted in practice variability and confusion. This systematic review aims to evaluate existing evidence on the safety, sustainability, and regulatory considerations of extended-use and reusable ABCs, and identifies gaps in Canadian guidance.

METHODS

We conducted a structured literature review using MEDLINE and Embase to identify studies evaluating extended use or reuse of ABCs with airway filters during general anesthesia. The initial search yielded 487 citations, which were screened for relevance; 145 full-text articles met eligibility criteria and were included for data extraction. Eligible studies included those that examined microbiological contamination risk, clinical safety outcomes, device

performance, environmental impact, cost considerations, and institutional practices related to ABC reuse in the operating room. In addition, practice guidelines and policy statements from Canadian and international anesthesia societies were reviewed to identify existing recommendations and areas of alignment or discrepancy regarding ABC reuse.

RESULTS

Our review suggests that extended-use ABCs, when combined with appropriate bacterial or viral filters and adherence to maintenance protocols, provide patient safety outcomes comparable to single-use systems in low- to moderate-risk cases. Four key domains were identified:

- **Infection risk:** Available microbiological and clinical studies, although limited, report a low risk of cross-contamination when filters are used correctly[2,3,4].
- **Safety evidence:** Evidence supports extended use for up to 7 days with a new filter per patient; however, data are derived from microbiological studies[1,4], small clinical series, and institutional experience, with no large multicenter trials identified.
- **Environmental and cost impact:** Each disposable circuit generates approximately 1.11 kg CO_2e[5], totaling 18,759 kg CO_2e annually for a moderate-sized hospital, with material cost reductions of up to 41% reported for extended-use circuits[3].
- **Guidelines:** No Canadian Anesthesiologists' Society guidance or consensus statements on extended-use or reusable ABCs were identified, contributing to institutional variability and uncertainty in practice.

DISCUSSION

The lack of robust clinical safety data and national consensus guidance remains a significant barrier to the adoption of extended-use ABCs in Canada. In the absence of clear professional recommendations, institutions remain hesitant and continue to default to single-use practices despite demonstrated environmental and economic benefits. Even amongst institutions that have adopted extended-use ABCs, circuit cleaning protocols are highly variable, and an evidence-based best practice is needed.

Multicenter safety studies, together with leadership from national and international professional societies, are essential to support the development of evidence-based, harmonized guidelines that advance both patient safety and environmental sustainability in anesthesia care.

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Life cycle assessment of three perioperative warming devices, single use water or forced air vs reusable direct conduction

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165

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INTRODUCTION

According to the World Health Organization, the climate crisis caused by human greenhouse gas (GHG) emissions presents a fundamental threat to human health. When accounting for both direct and indirect emissions, 4.4% of global GHG emissions come from health care. Indirect emissions accounting shows that the life cycle of medical goods is a large contributor to health care GHGs [1], with acute care hospitals and in particular operating rooms (OR) [2] being disproportionally responsible for procurement-related emissions. Anesthesiologists can significantly reduce healthcare environmental impact by integrating the triple bottom line (optimising patient care while minimizing social, financial and environmental costs) [3] into their practice. Reusable warming pads have been shown to be clinically equivalent to and less expensive than single use devices [4, 5], but thorough evaluation of the environmental impact of those devices is needed.

METHODS

The objective of this study was to quantify, using a standardized "cradle-to-grave" life cycle analysis (LCA) approach, the environmental footprint of three warming devices: a single use Forced Air underbody Blanket (FAB) (Model 635 from Bair Hugger; 3M); a single use Hot Water underbody Blanket (HWB) (Model Mult-T-Blanket 8001-061-810; Stryker Altrix) and a reusable Direct Conduction Mattress (DCM) (Model HotDog U102; Augustine Surgical Inc.).

The LCA was conducted according to ISO 14040 and 14044 standards. Extraction, production, assembly, packaging, distribution, use and end-of-life were included. The functional unit was one cardiac surgery carried out at the Centre hospitalier de l'Université de Montréal or at the Montreal Heart Institute, both in Montreal, Québec, Canada. TRACI quantified impact categories were studied: *Climate change, Human toxicity (carcinogenic and non carcinogenic), Photochemical oxidant formation, Ozone layer depletion, Fresh*

water ecotoxicity, Acidification, Eutrophication, and Particulate matter formation. OpenLCA software with the Ecoinvent (v3.11) inventory database were used to perform the LCA. We also evaluated two alternative scenarios: 1) the use of electricity from a standardized European mix during active warming; 2) the recycling of 100% of the disposable devices while the reusable pad was sent to landfill.

RESULTS

Our results show the reusable warming device has the lowest environmental footprint over all impact categories and in all scenarios. For example, in the base scenario, the indicator results for *Climate change* were 1.85 kg CO2-Eq for the FAB, 2.14 kg CO2-Eq for the HWB and 0.055 kg CO2-Eq for the DCM (97% less GHGs than HWB). The European electricity mix increased the environmental footprint related to the use of all devices but did not alter the conclusion that the reusable DCM generated a much smaller environmental footprint than the single-use devices. Recycling reduced the environmental footprint of the disposable devices but did not come close to making the single-use devices environmentally competitive with the reusable DCM.

DISCUSSION

Active warming devices are used to maintain patient normothermia during general anesthesia. Reusable warming pads are as effective and less expensive than disposable devices [4, 5]. This LCA shows that the use of a reusable DCM to maintain patient normothermia, rather than single-use alternatives, strongly reduces the environmental footprint of intraoperative active warming. Anesthesiologists can integrate these results with previous findings into their triple bottom line analysis to choose the best device to provide high quality, financially and environmentally sustainable care.

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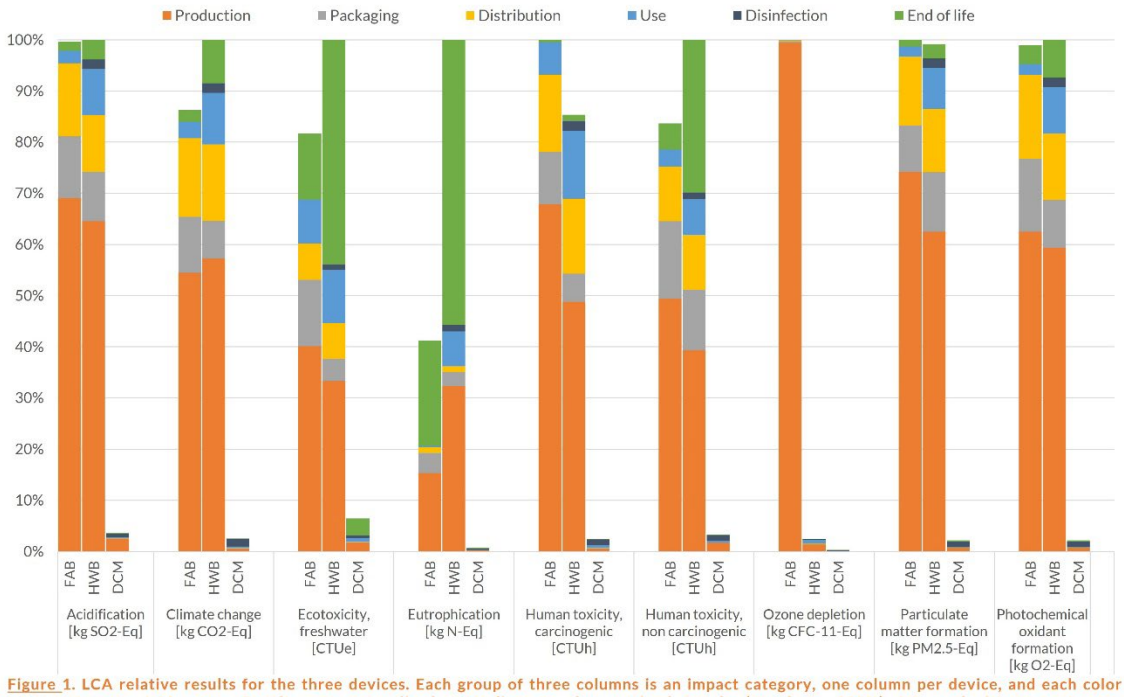

Figure 1. LCA relative results for the three devices. Each group of three columns is an impact category, one column per device, and each color represents one LCA step. Results are normalised according to the maximal result (equal to 100%) for each impact category. FAB: Forced Air Blanket, HWB: Hot Water Blanket, DCM: Direct Conduction Mattress